Bulletin of the Government Museum Chennai

Tourism Endowment Lecture

"Man and Mushroom"

By

Dr. V, Kaviyarasan, *M.Sc., Ph.D.,*
Senior Lecturer, Centre for Advanced Studies in Botany,
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FOREWORD

Conservation of earth's biosphere is the prime objective of the United Nations Environment Programme (UNEP), engaged in the co-ordination of intergovernmental measures for monitoring and protecting the environment, in order to achieve sustainable development and to resolve certain biodiversity issues. It has the following there-fold mandate: 1) To create awareness on global environment problems 2) To evolve consensus on actions addressed towards these problems 3) To promote and support such action programmes.

This lecture addresses the above objectives for creating awareness on the mushroom biodiversity of South India, and explains their role in soil nutrition. The edibility, cultivation and medicinal properties of commercially cultivated mushrooms have been highlighted. The author also gives details on how these fungi could be applied to address the present day problem of organic waste disposal in an Eco-friendly manner. For community development we have to think globally and act locally. This lecture gives an overview for mushrooms and their biotechnological potential.

Tourism endowment lecture has been instituted by N.Srikrishnan, Director, Mayur Travel Corporation, Nandanam, Chennai-35. The first lecture was arranged on 31.12.2003 on Mural Art Tradition of Kerala by Dr.T.Satyamurti, Superintending Archeologist, ASI, Chennai-9. This is the second lecture in the series, on 'Man and Mushroom' to be delivered by Dr.V.Kaviyarasan, Senior lecturer, Centre for Advanced studies in Botany, University of Madras, Chennai. This lecture in the form of a booklet to create awareness on Eco-friendliness is brought out by the Department of Museums.

Dr.T.S.Sridhar,Ph.D.,I.A.S., Principal Secretary/Commissioner of Museums, Government Museum, Government of Tamilnadu for his support to add a display of mushroom in the Gallery of the Government Museum and to bring out this booklet as Museum Publication.

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Man and Mushrooms

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The earth is covered by a layer of biologically active zone known as biosphere. The biosphere is a fascinating and a complex system that supports around 30 million species of plants, animals, fungi, protozoa and bacteria. These organisms play a major role in the maintenance of the environment. The importance of the study of these diversified organisms was realized only after the earth summit held in the year 1992 at Rio-de Janeiro. Biodiversity refers to the genetic, or taxonomic variability, within a specific area or region (Table 1).

The taxonomic diversity of these groups of organisms is known as taxonomic diversity. Biodiversity has now been broadened to include biological and geographic entities such as genetic diversity (genes and chromosomes), taxonomic diversity (species, genera, family, phyla, etc.,) and biogeographic diversity (biological regions landscapes, ecosystems, habitats).

Table.1: Comparision of known and estimated species of some selected groups of organisms (Hawkworth, 1991)

Group	Reported Species	Total Expected Species	Percentage
Vascular Plants	2,22,000	2,70,000	81
Bryophytes	17,000	25,000	68
Algae	40,000	60,000	67
Fungi	72,000	15,00,000	5.1
Bacteria	3,000	30,000	10
Viruses	5,000	1,30,000	4
Insects	9,50,000	15,00,000	6.4

Whittaker (1969) broke the tradition of three- kingdom system of classification of living organisms. He recognized five kingdoms namely Monera, *Protista*, Myceteae, Plantae, and Animalia. The kingdom Mycetae/Fungi stands out from other kingdoms based on the members mode of nutrition (absorptive), presence of chitin in the cell wall instead of cellulose and their lysine synthesis pathway etc. Presence of zoospores and their genomic analysis also confirms the kingdom fungi are more related to animal kingdom rather than photosynthetic plant kingdom. In an attempt to recognize monophyletic groups, the organisms once classified as fungi, are now placed in three different groups, the monophyletic kingdom Fungi, Stramenopila and Protista.

The three kingdoms of fungi recognized in the eighth edition of the Dictionary of Fungi (1995) are CHROMISTA, FUNGI and PROTOZOA. The Chromista are unicellular, filamentous or colonial eukaryotes which are primarily phototrophic and have cellulosic cell walls lacking chitin and β-glucan. Three fungal phyla recognized under Chromista are the Hyphochytriomycota, Labrinthulomycota and Oomycota. The Hyphochytriomycota comprise saprobes on plant and insect detritus or parasitic on algae and fungi, which are aquatic reproducing by zoospores with one anterior flagellum. The Labrinthulomycota consists of two orders the Labrinthulales and Thraustochytriales. They occur in fresh water as well as marine habitats associated with higher plants or algal chromists.The third order Oomycota are wide spread in aquatic as well as terrestrial habitats and include several economically important plant pathogenic fungi. The vegetative thallus in unicellular or mycelial, the hyphae being aseptate and coenocytic. The zoospores are biflagellate with one flagellum being of the 'tinsel' type having two rows of mastigosomes (hair-like structure covering the surface) and the other as whiplash type (with smooth surface or covered by fine flexous hairs). The cell walls contain glucan-cellulose and rarely small amounts of chitin. The Oomycota are regarded as derived from algal ancestors and are separated from the Eumycota or "True Fungi". Thus, the so- called fungi are not one group but an assemblage of true fungi including phylum Chytridiomycota, Zygomycota, Ascomycota and Basidiomycota.

Fig.1: Classification Of Fungi (Alexopoulous, 1992)

KINGDOM FUNGI

Phylum Chytridiomycota Phylum Zygomycota Phylum Ascomycota Phylum Basidiomycota

KINGDOM STRAMENOPILA

Phylum Oomycota Phylum Hyphochytriomycota Phylum Labyrinthulomycota

PROTISTS

Phylum Plasmodiophoromycota

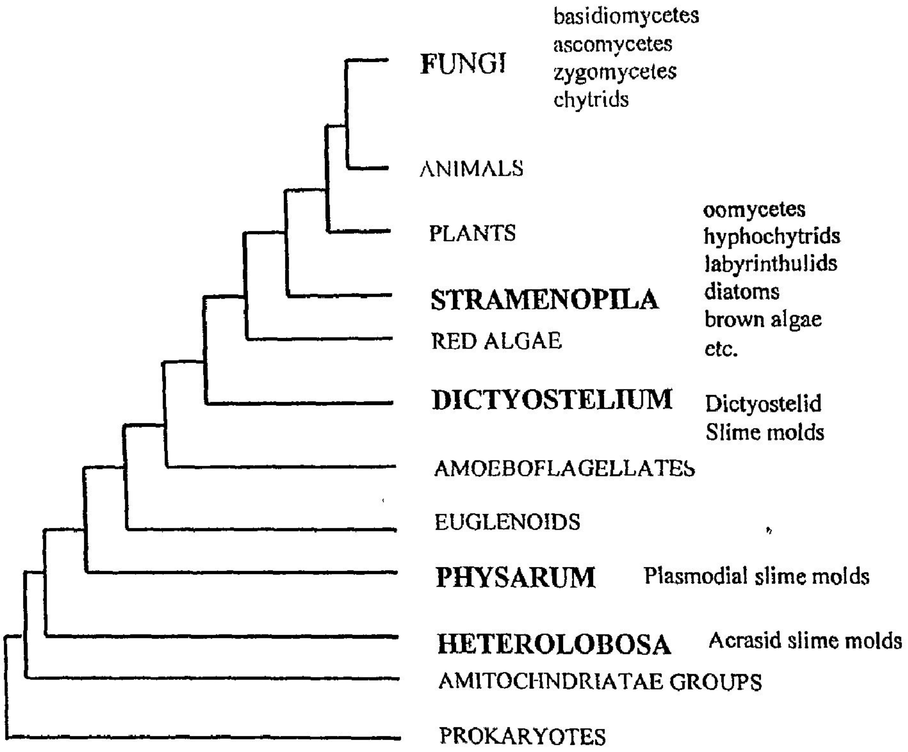
Phylum Dictyosteliomycota

Phylum Acrasiomycota

Phylum Myxomycota

Thus they exhibit a great diversity in containing organisms belonging to different kingdoms. According to rough estimates, there are over 72,000 species of fungi known and only 5% of the estimated species of fungi have been reported or discovered so far (Hawksworth *et al.*, 1995).

Fig.2: Phylogenetic Position Of Fungi In Evolutionary Tree



Recent research suggests that fungal biodiversity is much higher than previously thought. Nearly 145 different species of microfungi have been found in very small samples of fresh and decayed leaves from the forest floor of tropical rain forests. The numbers of macro fungi alone in United Statse have been estimated to range from 5000 to 10,000 species (http;//www/herb.Isa.umich.edu/kidpage/Biodiversity.htm). However, in India the inventorying of fungi has been started by the Ministry of Environment and Forests under the programme All India coordinated project on "Taxonomy of Fungi" at CAS in Botany, University of Madras, one of the nodal centres for the study of higher fungi (Mushrooms).

In the 20th century mycologists focused on particular crop plant pathogens, but in the latter part interest spread to survey and systematics, leading to increasing information on some classes like deuteromycetes, cup fungi, mushrooms etc., leading

to some genera of fungi representing large number of species like *Agaricus, Alternaria, Cercospora, Puccinia, Septoria,* etc. These genera may be found diverse in habitats.

Some of the roles played by fungi in ecosystem are listed below:

- Saprophytic fungi play a major role by breaking and recycling nutrients of dead plants and animal remains. Recycling of organic matter by decomposition/mineralization helps in transport of minerals and organic nutrients from soil to plants.
- Recycling of litter by the litter inhabiting fungi, otherwise the earth surface will be piled up by debris of all kinds.
- 85 to 90% of vascular plants enter into symbiotic associations with mycorhizzal fungi providing many trace elements and nutrients to the host.
- Bio-control agents such as *Trichoderma* spp., *Verticilium* spp., are used to control plant pathogens.
- Some are involved in carbon entrapment and enhance nitrogen fixation.
- Some are important ecological indicators (Lichens)
- Some are economically important potential source of food (Mushrooms, Cheese, Fermented food etc.)

Fungi play an important role in the modern life. Life saving medicines like Penicillin, Cyclosporin, ethanol a bio-fuel and the beverages like wine, beer, whisky etc., many enzymes are used in the detergent and food industry, and edible mushrooms a protein rich and medicinally valuable food are all products of fungi.

Out of total fungal species described from India, Deuteromycotina comprises (45%) followed by Basidiomycotina (Mushrooms) (20%)Ascomycotina (10%) Zygomycotina (5%) and Mastigomycotina (5%). Prof.C.V.Subramanian the former President of IMI (International Mycological Institute) former director of CAS in Botany described 35% of the total fungi reported from India.

Macrofungi:

These groups of fungi consist of members of both Basidio and Ascomycetes which are clearly visible to the naked eye. Mushrooms (Agaric and Aphyllophorales and few ascomycetes) are involved in the decomposition of complex organic molecules such as cellulose, hemicellulose and lignin. Mushrooms can be broadly classified into three groups based on their nutrition, Saprophytes, Parasitic, and Symbiotic.

Saprophytic

These groups of fungi obtain nutrients and energy from the breakdown of dead and decaying organic matter of both plants and animals. This is mostly found on dead wood and litter, but also includes animal skin, bones and horn. In the process the fungi obtain nutrients by break down of organic matter.

Parasitic

These groups of fungi obtain their nutrients by parasiting other organisms without any benefit to the host. They are parasitic on trees, vegetables, caterpillars, larvae, wattle goat moth etc. They decompose and recycle the nutrients.

Symbiotic

These groups obtain nutrition by a mutual relationship with plants especially trees. One of the forms is the mycorrhizal association with the roots of tree species. eg. *Amanita* spp., *Russula* spp. These fungi inturn help plants in the uptake of nutrionally important minerals like phosphorus and nitrogen. They also accumulate toxic heavy metals like Chromium, Vanadium etc., in the mycelium and protect the roots of higher plants from pathogens and heavy metal toxicity. Eighty five percent of higher plants have association with ecto or endo mycorrhizal fungi; clearly show their importance in the nutrition and sustainable growth of the higher plants. Many evidences prove their association dating back to Precambrian period when the terrestrial habitat of higher plants established.

Though their fruit bodies longevity vary from species to species, their mycelia abundantly present always in their substrate (Humus, wood, soil etc.,) There are records of fungal colonies (*Armilleria melia*-honey fungus) spread over 1500 acres

and age of the colony was estimated as 400 years and their biomass may weigh around 150 tons. This clearly indicates by just maintaining the natural habitat the mushrooms can be conserved *in situ.*

Cord forming fungi are the fungi forming network of filamentous aggregation of mycelium, covering a large area in the litter. These cord-forming fungi are potential channels for the translocation of nutrients between any two or more colonized food base. Robin sen *et al* (2005) elaborated that the nutrients from well grown wealthy trees are transported to the week trees growing under shades through mycorrhizal net work using radioisotape techniques. The sporocarp formation in macrofungi shows periodicity more strongly related to the climatic conditions and moisture content of the substrate. Fluctuations found in sporocarp productivity from year to year, can be distinguished as quantitative (yield) and qualitative fluctuations, even a species may be absent in a certain year. It has been recorded that within few acres of land four hundred species of macrofungi (mushrooms) in the period of five years. But some of the species that were recorded in one year did not appear in another subsequent years.

Though many environmental factors such as climate change, competition for the space and nutrients and predators are the major reasons for these declines of the important group of organisms, only we and the so called infrastructure development activities resulted in destruction of many habitats, and the air polluted by the chemical industries. Hence the developmental activities are to be taken up by sparing some areas of habitat, by which the biodiversity of these organisms can be preserved *in situ.* Mushroom eating habitats are traced back to the Vedic periods. Gordon Wason the German banker cum mycologist after researching at Mexico, Pune and Lucknow declared that soma drink is nothing but the mushroom soup of *Amanita muscaria* a hallucinogenic fungus having mycorrhizal association with pine trees (Wason).

As early as 1847 one Dr. Petch the curator of the Gandy Botanical Garden Srilanka visited Tamil Nadu and recorded many observations. In Tanjore district he has recorded that some persons were digging a termite –mounds, on enquiry he was revealed that mycelial sclerotium found in the bottom of termite mound locally called

as "Puttru Manga" was given as food / medicine to the pregnant ladies before delivery by which the 'Pneumonia fever' will be prevented to those mothers normally occur during those periods. Even in Sangam Tamil literature many references are made about mushrooms (Samy, 1957).

Even today wild edible mushrooms eating habit are prevailing in the South Tamil Nadu and among forest tribes. They have the knowledge about poisonous and edible mushrooms. *Auricularia* spp., were consumed directly by some of the tribes at Paechiparai forest in Western Ghats of Tamil Nadu. Many *Lentinus* spp., are growing on live /dead trees are cooked with rice and consumed as food additives. (Kaviyarasan *et al.*, 2009).

MUSHROOM RESEARCH IN TAMILNADU

Through Prof C.V.S. has initiated the mycological research, Prof. K. Natarajan (1941-2008) has pioneered the research on mushrooms. He has described more than 800 species of mushrooms belong to Agarics and Aphyllophorales (wood inhabiting fungi). Many *Termitomycetes* spp., such as *T.heimii* , *T.microcarpus, T.clypeatus* were described by him. All these mushrooms are consumed in many parts of India.

The most expensive edible fungi are collected from wild such as, truffles and morels. Both are belongs to Ascomycetes. One kilogram of morels, (*Morchella esculenta, Morchella delisiosa*) are cost around Rs.8000 (kg) kilogram. Though this mushroom is known to available at the Himalayan ranges, we have reported their availability also in Kodaikanal Hills (Kaviyarasan *et al.*, 2007).

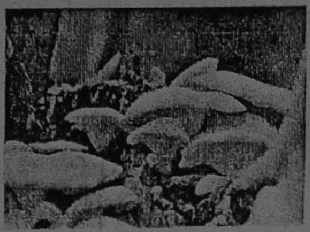
Edible Mushrooms:

Mushrooms have attracted the attention of man from very ancient times and use of mushroom as food is as old as human civilization. In ancient religious writings like the Vedas and Bibles there are references on the occurrence of mushrooms and their utilization as food as well as in medicine. It has been estimated by the United Nations Food and Agriculture organization (FAO) that the global demand for protein will have almost doubled by the end of this century, and it has been calculated that it will be impossible to satisfy this future requirement by means of systems based

on conventional agriculture and fishery methods. One of the alternatives available is to use fungi directly as protein producers.

Pleurotus roseus

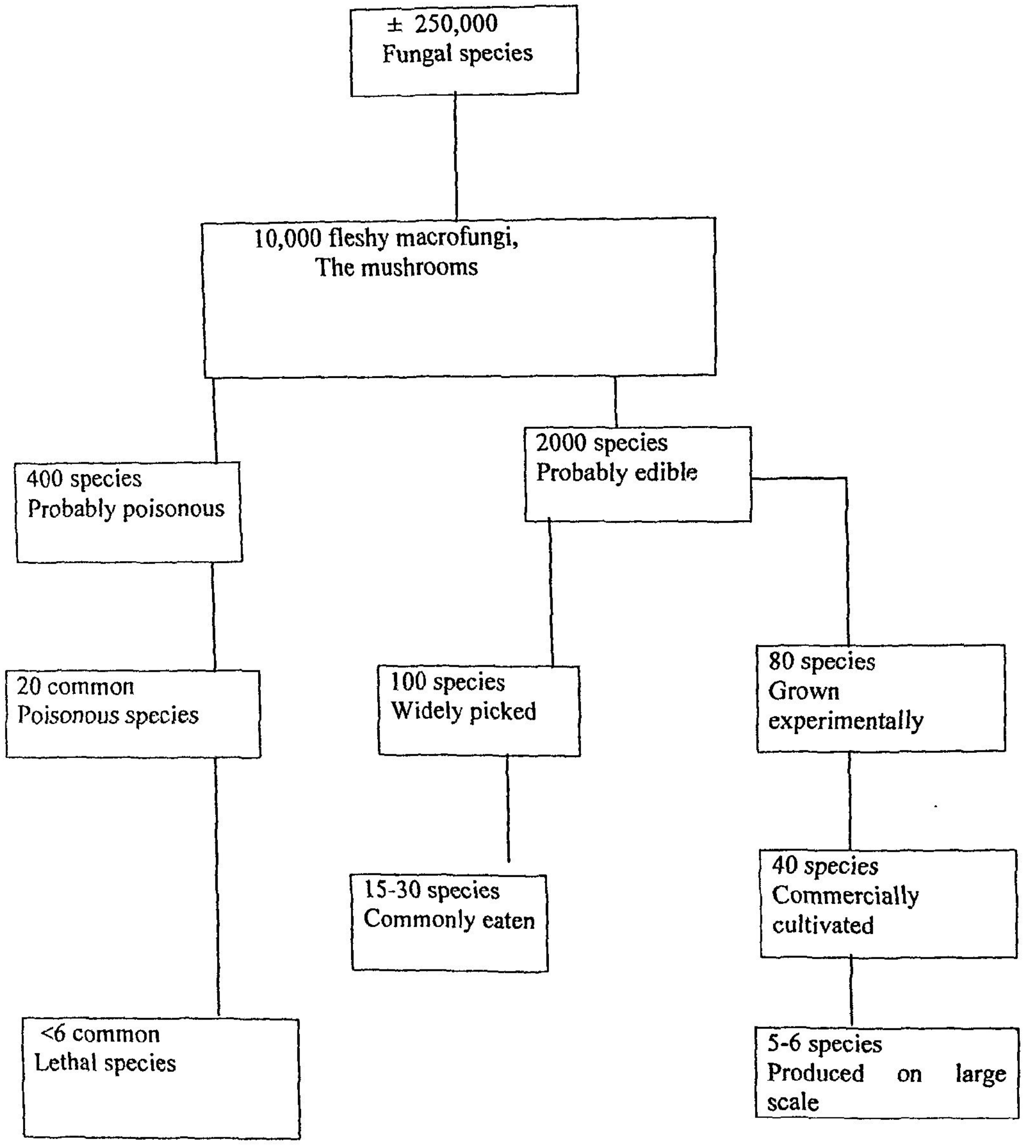
Volvariella volvaceae



Pleurotus cystidiosus

In nature, mushrooms grow wild in almost all types of soils on decaying organic matter, wooden stumps, etc. They appear mainly during rainy season wherever organic matter or its decomposition products are available. There are more than 1000 species of edible mushroom reported in literature from different parts of the world. Out of 20,000 fleshy macro fungi (mushrooms) 2000 species are probably edible of which 20-25 types of mushrooms are being cultivated at commercial level while only 4-5 mushrooms are cultivated at industrial level. While only 400 sp are poisonous, of which 6 species are deadly poisonous.

Fig.3: Culinary Classification Of The Fungal Kingdom



Though mushrooms poisoning is not a major public health problem some of the mushrooms had been used to poison several Roman kings and consequently had caused to their Government toppled. Hence Voltaire the historian declared a pot of

mushrooms changed the history of Europe". Later in the modern world, many people were killed by mushroom poisoning as well.

The deadly poisonous *Amanita phalloides* was employed to kill the Roman kings Claudius I by his third wife Aggripina. She requested her husband that her son should be crowned as king after him. But he refused and said that Brittanicus his first wifes son is the legal heir. So she planned carefully and involved many persons including a Royal physician *Locusta, Xenophus* and her son Nero. In the dinner she served dishes made of *Amanita caesareo* mushrooms highly preferred by Roman nobility, and soaked the dishes with juice of *Amanita phalliodes*. This was recorded by the Pliny the great historian in his book Natural history of the world A.D 22. The death of Tsar Alexius of the present day Russia in 1723, was well recorded in the book History of house of Austria written by William Cox 1940. In the 1918 one French man, who had good knowledge of mushrooms and insurance. His modus operandi was that he would make friend with individuals or couples who were relatively wealthy. After selling the insurance policy to the wealthy people tactfully he named himself as a sole beneficiary of the policy. He would entertain them at appropriate time and feed them with *Amanita phalloides* poison. Later he was caught and sentenced to death (Findlay, 1982; Ramsbottom, 1953). The toxin involved in the above said murders is Amatoxin, which is not only present in *Amanita* but also in so many other genera such as *Galerina* sp., *Lepiota* sp., *Conocybe* sp. North American mycological association recorded 9482 mushroom poisoning cases in the year 1991 alone (Trestrail, 1992). In India in the same year first report on mushroom poisoning was recorded (Natarajan and Kaviyarasan, 1991). In Japan alone 10924 mushrooms poisoning cases were recorded with 72 deaths in the period between 1959 and 1988. Mass poisoning was recorded in Poland, where 140 people were poisoned of which 18 were children and 4 of them succumbed to this poisoning in the year 1989 (Kacic *et al*., 1990). In September 1992 mushrooms poisoned nearly 400 peoples, with as many as 100 deaths (Fourre, 1993).

Many efforts were made to identify the types of poisons and their chemical nature (Benjamin 1995). Presently eight types of mushroom toxins were classified on the basis of their chemical nature and mode of action on the human system. Some people are afraid of mushrooms since some are deadly poisonous. There is no fool

proof method to separate the edible mushrooms from the poisonous ones. Cases of poisoning by mushrooms are usually grouped into the following types of syndromes:

1) Phalloides syndromes (latent period usually 8-12 hours, then severe vomiting and diarrohea; later symptoms of liver damage. eg. *Amanita phalloides*).
2) Gyromitra syndrome (similar to phalloides syndrome; often additional central nerves and haemolytic symptoms eg. *Gyromitra esculanta.*
3) Muscarine syndrome (latent period short; gastero intestinal disturbances; sweating, saliation and lachrymation eg, *Inocybe* spp.).
4) Pantherina syndrome (latent period short: symptoms like those of alcohol intoxication, then deep sleep; eg. *Amanita muscaria; A.Pantherina*).
5) Psilocybin syndrome (latent period short; psychotommetric symptoms predominate, similar to those of LSD intoxication eg. *Psilocybe mexicana*).
6) *Coprinus* syndrome (symptoms of poisoning only after the consumption of alcohol; reddenining of the face, head-ache, metallic taste in the mouth eg. *Coprinus atramentarius*);

Gyromitra esculenta

Amanita muscaria

Amanita phalloides

Mushrooms have been and will be increasing in importance as a source of food because they have a pleasing flavors, fine texture, and good protein content and favorable health benefits. Their food value is similar to that of most common vegetables. In India, it has added importance in view of the vegetarian habits of a considerable proportion of the population. Amongst the edible species only cultivated ones can provide a stable supply. Mushrooms can be grown successfully on a wide variety of inexpensive substrates such as agricultural and industrial by products and residues. Spent compost from mushroom industry is also good manure containing appreciable quantities of nitrogen.

The cultivation of mushrooms in its primitive forms must have been a very ancient art of cultivation of Jews Ear Fungus (*Auricularia* spp.) has been recorded in ancient Chinese literature dating back to around 300 B.C. Authentic records are available only for *Agaricus bisporus* (white button mushroom), the cultivation of which was started in Paris around 1650 by melon growers.

Table.2: List Of Edible Mushrooms

1.	*Agaricus bisporus*	20.	*Flammulina velutipes*
2.	*Agaricus bitroquis*	21.	*Oudemansiella canarii*
3.	*Agaricus brunnescens*	22.	*Tricholoma giganteum*
4.	*Agaricus campestris*	23.	*Tricholoma lobayense*
5.	*Agaricus arvensis*	24.	*Tricholoma matsutake*
6.	*Agaricus silvaticus*	24.	*Agrocybe aegerita*
7.	*Pleurotus ostreatus*	25.	*Calocybe indica*
8.	*Pleurotus sajor-caju*	26.	*Coprinus comatus*
9.	*Pleurotus citrinopileatus*	27.	*Coprinus fimetarius*
10.	*Pleurotus flahellatus*	28.	*Kuehneromyces* sp.
11.	*Pleurotus roseus*	29.	*Pholiota nameko*
12.	*Pleurotus florida*	30.	*Stropharia rugosa-annukaa*
13.	*Pleurotus cystidiosus*	31.	*Auricularia auricula*
14.	*Pleurotus fossulatus*	32.	*Auricularia polythricha*
15.	*Pleurotus squarrolosus*	33.	*Auricularia delicata*
16.	*Lentinus edodes*	34.	*Auricularia mesenteric*
17.	*Lentinus cladopus*	35.	*Auricularia comeae*
18.	*Lentinus squarrulosus*	36.	*Auricularia peltata*
19.	*Volvariella volvaceae*	37.	*Auricularia fucosuccinea*

Of the hundreds of edible species of fungi gathered throughout the world less than ten species are cultivated commercially. In order of world production, the white button mushroom, *Agaricus bisporus* (including *A.bitorquis*) heads the list with a total tonnage in excess of 750,000. The second most popular fungus, *Lentinus edodes*(shiitake mushroom), is grown mainly in Japan and the Far East with a total annual production in excess of 180,000 tones. *Volvariella volvacea,* commonly called the paddy straw mushroom has been cultivated in China and other Asian countries for about 2000 years and presently about 65,000 tones are produced annually. *Flammulina velutipes,* otherwise known as the "winter mushroom" is grown in Japan

and Taiwan. *Pleurotus* spp., cultivated initially in the Far East countries but now in India and European countries, has an estimated production of 40,000 tones and is steadily increasing. A number of other fungi of lesser importance grown in Japan and the Far East include *Pholiota nameko, Auricularia polytricha* and *A.auricula-judae, Tremellla* spp., *Kuehneromyces mutabilis, Stropharia rugosa-annulata* and *Coprinus comatus.*

Table.3: World production of cultivated edible mushrooms in different years

Species	1981		1990		1997	
	Fresh Wt.	(x 1000 MT)	Fresh Wt.	(x 1000 MT)	Fresh Wt.	(x 1000 MT)
A.bisporus/bitorqus	900.00	71.6	1424	37.8	1955.9	31.8
Lentinula edodes	18.0	14.3	393.0	10.4	1564.4	25.4
Pleurotus sp	35.0	2.8	900.0	23.9	875.6	14.2
Auricularia	10.0	0.8	400	10.6	458.3	7.9
Volvariella volvaeceae	54.0	4.3	207.0	5.5	180.8	3.0
Flamumulina	60.6	4.8	143.0	3.8	284.7	4.6
Tremalla	--	--	105.0	2.8	130.5	2.1
Hypsizygus	--	--	22.6	0.6	74.2	1.2
Pholiota	17.0	1.3	22.0	0.6	55.5	0.9
Grifola frondosa	--	--	7.0	0.2	33.1	0.5
Others	1.2	0.1	139.4	3.7	518.4	8.4
Total	1257.2	100	3763	100	6158.4	100
% increase	--	--	--	72.5	--	25.4

Ref: Chang and Miles, 2004.

Mushroom cultivation represents the only current economically profitable biotechnology process for the conversion of waste plant residues (lignocelluloses) from forestry / Agriculture. Mushroom cultivation is also the only microbiological production system which can bioconversion all the major plant polymers, lignin, cellulose and hemi cellulose from such residues.

Substrates from commercial mushroom production are normally prepared from waste agricultural or forest product materials using ingredients such as cereal straws, manures, corn cobs or other crop residues, saw dusts and logs. In certain cases the substrates will be inoculated directly and require very little pretreatment, eg. *Lentinus edodes* production using logs. In other cases the substrate will be pretreated microbiologically or physically. Microbiological pretreatment normally comprises some form of controlled bulk composting process. Physical pretreatment could include steam treatment or sterilization by autoclaving. Substrate for fungal growth can be prepared as sterile materials, to produce an axenic growth medium eg, bottle cultivers of *Flammulina velutipes* or be non-sterile, eg, compost substrates to produce *Agaricus bisporus*. Medium composition can either be that solely of the raw materials such as straw, saw dusts or wood or in appropriate cases supplemented at preparation or later stages of their processes with nitrogen and / or carbon – containing materials. Many of the lignocelluloses sources are relatively poor in nitrogen and can be added as manures or other organic or inorganic nitrogen compounds. These may be particularly required if a compositing stage is used. This additional nitrogen is essential to produce a large active microbial population during the composting stages.

Many mushroom cultivation systems are completely non-axenic, i.e., they are exposed at most times to microbial contamination. The substrates are usually inoculated with a pure culture (mushroom spawn) of the fungus. These are prepared on cereal grains, wood chips or plugs or other materials in bottles, bags, etc. This is the only axenic part of the whole cultivation process. Mushroom cultivation is subject to microbiological hazards in a variety of ways. Viruses, bacteria and fungi can interfere with various stages in the production stage and cause crop losses. Fungal viruses were first reported in edible fungi (*Agaricus bisporus*). Bacterial pathogens include various *Pseudomonas* spp., particularly *P. tolaasii*. Several fungal diseases can occur which damage the fruit body tissues. The major pathogens for *Agaricus* are species of *Verticillium* and *Mycogone*.

***Agaricus bisporus* Cultivation:**

There are two distinct operations in *Agaricus* cultivation. The first is the controlled production of composted substrates using mixtures of plant residues and

manures or other nitrogen rich materials as activators to stimulate microbial growth. This stage takes up to 3 weeks. The second part is the inoculation of the substrates with mycelium of *Agaricus*. This will normally result in mycelial growth of the fungus and by suitable manipulation of the culture fruiting is induced. This stage will take about 5 weeks. This process is known as composting. Agrowaste such as straw (Rice/Wheat straw) are heaped and watered. Microbial growth was induced. In the centre of the heap the temperature will rise up to 70-80C. This temperature kills all the mesophilic fungus and encourages the thermophilic organisms. By turning the compost heaps from 6 to 12 times. During every turn nitrogen sources such as urea and cow/horse dung or chicken manure are added. Finally when no ammonia smell left the compost was declared fit. This is Long Method of Composting (LMC). In Short Method of Composting (SMC), after adding all the ingredients in 4 or 5 timing they are kept in a tunnel and steamed for 24 hour steam at 80C. Then the temperature is brought down to slowly at 35-40C. This process is known as 'Peak Heating".

In The second part is the inoculation of the substrates with mycelium of *Agaricus*. This will normally result in mycelial growth of the fungus and by suitable manipulation of the culture fruiting is induced. *This stage will take about 5 weeks.* In view of the scarcity of horse manure in certain areas alternative substances of vegetable origin suitable for mushroom production are also used. These are referred to as "Synthetic Composts" as opposed to the word "Natural Compost" used for manure-wheat straw mixture. The compost is filled into trays or shelves. Usually 10kg of natural compost is filled per square foot of 6" deep tray. Spawning is carried out when the compost reaches a temperature of 24-25° C. After spawning the trays are held in spawn run rooms at a temperature of 24-25 °C and a relative humidity of 80-90%. Now a day's polypropylene bags are used instead of wooden trays.

The practice of placing a thin layer of soil or peat on top of the compost, after the spawn has run through it, is called casing. Fruit body initiation is induced by this process. Microbial activity in this layer is responsible for the initiation of fruiting combined with lowering of the Co_2 concentration in the ambient air surrounding the cultures. Further the nutrient stress in the layer are also induces the mycelium. Fruit body initials rise approximately two weeks after casing and then mature fruit bodies appear in a series of cycles (flushes) over intervals of 7-10days. In commercial

cultivation only four or five flushes are normally harvested. The first two flushes have the greatest bio-mass and then yield decreases at each subsequent flush.

Cultivation of *Lentinus edodes* (Japanese mushroom or shiitake)

It has been estimated that there are over 2,30,000 growers in Japan. This wood destroying fungus produces attractive brown-red fruit bodies and is sold both as the fresh and dried product. In nature *L.edodes* grows on the wood of broad leaved trees, mainly the family Fagaceae (*Quercus* spp., *Castanopsis cuspidate*, *Castanea crenata*, etc). It is artificially cultivated on the wood of *Quercus* spp. The preparation of a good "bed-log" is the most important pre-requisite in the production of these mushrooms. Trees are normally felled in the autumn, when the sugar content of the wood is high after leaf fall. The felled timber, generally 5-15 cm in diameter, is cut into 1m length and stored for 30-60 days before inoculation. Usually 15-20 inoculation points are made to each bed-log. After inoculation the logs are placed in a "laying yard" in an obliquely upright position at a small angle. The fruit bodies start appearing from the second year onwards. In Taiwan *L. edodes* is now being grown commercially on saw dust mixtures supplemented with a variety of nitrogen rich plant materials such as soya bean meal and rice bran are known as 'synthetic logs'.

The fruit bodies are rich in vitamin D. It is also reported to contain a number of substances effective against blood cholesterol (eritadenine), anti tumor principle (lentinan) and substances inhibitory to the development of AIDS (lentinan sulphate).

Cultivation of *Volvariella volvacea* (Paddy Straw Mushroom)

The fungus is known as a delicacy for many centuries in China and other Asian countries. It is mainly grown in paddy straw. In recent years the productivity of this fungus per unit weight of substrate has been improved by growing it on a combination of rice straw and cotton waste. In Hong Kong cotton waste compost is prepared by mixing it with lime stone and chicken manure. 10cm thick beds of this compost are arranged in their within polythene growing houses. No casing soil is necessary to initiate fructification. Under controlled condition the fruit bodies appear on the compost surface 15days after spawning.

Cultivation of *Pleurotus* spp.

Pleurotus spp. is wood destroying saprophytic fungi. Because of their shape they are commonly called as "Oyster Mushrooms". In temperate countries *P. ostreatus* is the commonly cultivated species. In tropical countries such as India species *Pleurotus sajor-caju, P. citrinopileatus* and *P. flabellatus* are commonly cultivated in shredded straw substrate supplemented with nitrogenous substances. Grain spawn is used from inoculation. The substrate is packed in polythene bags and kept in a dark room at 25-30C with 80% humidity. Depending on the strain, complete colonization of the substrate is achieved in 2-3 weeks. The fruiting is light-dependent. Fruit bodies start developing about 2 weeks after complete spawn running. Two to three flushes of fruit bodies can be harvested.

Nutritional and Medicinal properties:

In the early 1990's due to awareness about nutritional and medicinal properties the mushroom eating and cultivation had increased around the world.

Compared to all the vegetables mushrooms have higher proteins (18-35%) except soya bean. Further the available proteins are also of high quality having all the essential amino acids which are available mostly from animal sources. Hence for vegetarian's mushrooms are good sources of essential amino acids thus the proteins available from mushroom are of high quality. Similarly essential fatty acids are also available. Mushrooms are also good source of vitamins. Thus eating mushrooms are equal to intake of vitamin tablets.

They have very less amount of carbohydrates and are stored as sugar alcohols such as mannitol or glycogen which are easily utilizable. Further, these carbohydrates are responsible for antitumor activities rather than the proteins. Antioxidant and anti cancerous properties were determined for most of the edible mushrooms.

MUSHROOMS AS FOOD AND NUTRITION

Since earliest times, mushrooms have been treated/used as a special kind of food. The Greeks believed that mushrooms provided strength for warriors in battle. The pharaohs prized mushrooms as a delicacy, and the Romans regarded mushrooms

as the "Food of the Gods," which was served only on festive occasions. The Chinese treasured mushrooms as a health food, the "elixir of life". The Mexican Indians used mushrooms as hallucinogens in religious ceremonies and in witchcraft, as well as for therapeutic purposes (Chang S.T, 1993) serve very good healthy food, protein rich with lot of amino acids.

Protein

The protein content of edible mushrooms, in general, is about twice that of asparagus, cabbage, and 4 times and 12 times those of oranges and apples, respectively. On a dry weight basis, mushrooms normally contain 19 to 35% protein as compared to 7.3% in rice, 13.2% in wheat, 39.1% in soybean and 25.2% in milk

Fat

The fat content in different species of mushrooms ranges from 1.1 to 8.3% on a dry weight basis.

Carbohydrates

According to Crisan and Sands; Pentoses, methylpentoses, hexoses, as well as disaccharides, glucan, amino sugars, sugar alcohols and sugar acids are constituents of mushroom carbohydrates.

Vitamins

Edible mushrooms are a good source for several vitamins including thiamine (Vitamin B1), riboflavin (vitamin B2), niacin, biotin, and ascorbic acid (vitamin C).

The thiamine content	**The niacin content**
V. volvaceae - 0.35 mg	*L. edodes* - 54.9mg
A. bisporus -1.14mg to 1.16	*A. bisporus* - 55.7mg,
Pleurotus spp. - 4.80mg	*V. volvaceae* - 64.88mg
L. edodes - 7.8mg.	*Pleurotus spp.* - 46.0 to 108.7mg

Minerals

The minerals present in the substrate are taken up by growing mycelium and translocated to the sporophores. The highest mineral content is potassium followed by phosphorus, sodium, calcium and magnesium.

Mg 56-70%, Copper 12.2-21.9 ppm, Calcium 0.3-0.5 ppm, and Lead 1.5-3.2 ppm. Potassium account for 45% of the total ash content. Hence the easy way is utilize the waste land and also farm wastes. These farm wastes can be easily be converted into biofertilizer using fast growing fungus. The fungi not only converting the wastes into protein rich mushrooms, but also yields nitrogen rich spent compost.

Table.4:Essential Amino Acid Composition of Mushroom Species

Amino acid	***Pleurotus florida***	***Pleurotus sajor-ca ju***	***Pleurotus ostreatus***	***Agaricus bisporus***	***Volvariella diplasia***	***Lentinus edodes***	**Hen's eggb**
Leucine	7.5	7.0	6.8	7.5	5.0	7.9	8.8
Isoleucine	5.2	4.4	4.2	4.5	7.8	4.9	6.6
Valine	6.9	5.3	5.1	2.5	9.7	3.7	7.3
Tryptophan	1.1	1.2	1.3	2.0	1.5	nd	1.6
Lysine	9.9	5.7	4.5	9.1	6.1	3.9	6.4
Threonine	6.1	5.0	4.6	5.5	6.0	5.9	5.1
Phenylalanine	3.5	5.0	3.7	4.2	7.0	5.9	5.8
Tyrosine	2.7	6.3	3.0	3.8	2.2	3.9	4.2
Cystine	0.2	1.2	0.4	1.0	3.2	nd	2.4
Methionine	3.0	1.8	1.5	0.9	1.2	1.9	3.1
Arginine	3.2	6.2	5.3	12.1	8.3	7.9	6.5
Histidine	2.8	2.2	1.7	2.7	4.2	1.9	2.4
Total essential Amino acids	46.4	43.4	35.5	41.6	50.1	38.4	51.3

Note: nd= no data

Table.5:Total Protein and Non-Protein Nitrogen Contents of Mushroom Species

Species	Total N (% of dry wt.)	Protein N (% of Total N)	NonProtein N (% of Total N)
Agaricus bisporus	5.0	63	37
Boletus badius	6.4	69	31
Boletus edulis	6.4	71	29
Canthrellus cibarius	3.6	67	33
Gyromitra esculenta	5.0	70	30
Lactarius vellereus	4.0	57	43
Leccinum scabrum	5.6	72	28
Lepiota procera	7.0	47	53
Paxillus involutus	4.2	66	34
Pleurotus ostreatus	3.6	70	30
Suillus bovinus	4.3	61	39
Suillus luteus	5.1	77	23
Tricholoma equestre	2.6	62	38
Tricholoma nudum	8.8	43	57

Table.6:Vitamins of Basidiomycetes (mg per 100gm dry weight)

Species	Ascorbic acid	Thiamine	Niacin	Riboflavin	Pantothenic acid	Folic acid
Pleurotus flabellatus	144 ± 22	1.46 :t 0.21	73.3 ± 3.35	7.10 ± 1.32	33.3 ± 2.00	1222 ± 101
Pleurotus ostreatus		2.23 ± 0.33	66.6 ± 5.23	97 ± 1.11	24.3 ± 2.95	13461±120
Pleurotus sajor-caju	111±16	1.75 ± 0.23	60.0 ± 4.72	6.66 ± 1.22	21.1 ±3.11	1278 ± 130
Pleurotus florida	113 ± 15	1.36 ± 0.15	72.9 ± 5.33	7.88 ± 1.00	29.4 ± 2.93	1412 ± 150
Agaricus. sp	82	1.14	56.19	4.95	22.8	933
Auricularia	n.a	DJ6		0.48	n.a	n.a
Lentinus	n.a	0.40		0.90	n.a	n.a
Volvariella	n.a	0.32	59.5	2.73	n.a	n.a

Medicinal mushrooms have a long history of use in folk medicine and a part of oriental medicine for hundreds of years as beneficial for health. Mushrooms used as anti cancers drug for various organs are known in China, Japan, Russia, Korea as well as U.S.A., and Canada. Approximately 14,000 species are known from different parts of the world (the estimated number of mushrooms on earth is about 1, 40,000 species). In the tropics up to 70% of mushrooms are still to be described. Mushrooms comprise a vast and yet largely untapped source of powerful new pharmaceutical products. Some of the recently identified substances from higher basidiomycetes posses promising effects such as Antitumor, antiviral, immune modulating, antibacterial, antioxidant, antiparasitic, cardiovascular, hepatoprotective, antihyper cholesterolemic, antidiabetic.

Ice Man's Medicine Kit

Otzi or the Ice Man, who used mushrooms more than 5,000 years ago.

The discovery of the mummified human body known as the "Ice Man" in a glacier in the Italian Alps in September 1991 caused great excitement in the scientific world. Luigi Capasso, an anthropologist at the National Archeological Museum in Chieti, Italy, reported in *The Lancet* that the two walnut-sized lumps carried by this individual have been identified as the woody fruit of *Piptoporus betulinus*, a bracket fungus common in alpine and other cold environments. *P. betulinus* contains toxic resins and an active compound, agaric acid, which are powerful purgatives and result in bouts of diarrhea. The fungus also contains oils that are toxic to metazoans and have antibiotic properties, acting against mycobacteria.

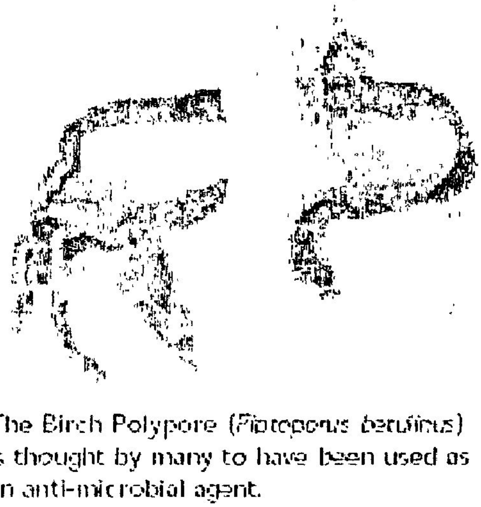


Fig.4: The fruit body of *Piptoporus betulinus* isolated from Iceman kit.

There are about 700 species of higher basidiomycetes that have been found to posses significant pharmacological properties. These are used as adoptogens and immuno-stimulants which are broadly categorized as "biological response modifier" (BRM) which modify the host's biological response by a stimulation of the immune system that may result in various therapeutic effects.

Three major drugs:

- Krestin-mycelial biomass of *Tremates versicolar*
- Lentinan-fruitbodies of *Lentinula edodes*
- Schizophyllan-liquid cultured broth of *Schizophyllum commune*

Many if not all mushrooms (basidiomycetes) contain biologically active polysaccharides in fruit-bodies, cultured mycelium, and culture broth. These polysaccharides are now considered as compounds which are able to modulate animal and human responses and to inhibit certain types of tumor growth. The exact mechanism of action of the Polysaccharides is unclear. These compounds may up or down regulate various aspects of tumoral and cellular arms of the immune system.

Agaricus bisporus	Hot water extracted-neutral acidic polysaccharides	Increased the survival rate of Sarcoma-180
Agaricus blazei	D-glucan protein complex, Water insoluble β –D-glucan + protein	Antitumor
Agrocybe cylindracea	Alkali soluble D-glucan	Antitumor against Sarcoma- 180; Inhibited growth of Sarcoma-180;
Flammulina velutipes	PA5DE; glucose: mannose; fructose with β1--3 and β 1 -- 6 glucosyl linkages	inhibited the growth of implanted Sarcoma-180 tumor in mice
Gandoerma lucidum, Agaricus campestres, Grifola frondosa	Polysaccharide of extracts	Anticomplementary activity
Leninus edodes	Polysaccharides; β-D-glucans	Antitumor against Sarcoma- 1 80
Polystictus versicolor	Hot water extractable,	Antitumor
Lentinus edodes	Polysaccharide	Stimulated immune function of mice
Pleurotus ostreatus	Heteroglycan. galactose, mannose and fructose glycosidiclinkage	Lowered cholesterol content in serum and liver
Polyporus confluens	*Polysaccharide*	*Antitumor activity*
Polyporus versicolor *Polyporus Umbellatus*	*Polysaccharide* Composed of mannose, galactose,glucose	*Antitumor* Prevention of liver *cancer*
Polystictus versicolor	Polysaccharide	Useful or prevention of lepatom

ANTIVIRAL EFFECTS

Cochran was the first to report that antiviral substances were present in mushrooms. This encouraged the screening of aqueous extracts of some Japanese mushrooms. As a result of this program, it was found that an aqueous extract of the

donko mushroom (*Lentinus edodes*) fruiting body , as well as the spores, contained antiviral activity against influenza A/SW15 virus infection in mice. The antiviral influenzal activity was mediated by the induction of interferon of the host. A phenol fraction of the mushroom extract was capable of conferring the antiviral activity. These results suggested that perhaps the RNA fraction of the mushroom extract was inducing interferon since double stranded RNA (ds-RNA) has been documented as being capable of inducing interferon.

Suzuki *et al.* (1976) confirmed that the interferon-inducing activity is due to the ds-RNA from the spore extract of *Lentinus edodes*. The origin of this ds-RNA was ascertained to be derived from the mycophages attached to the spore and the fruiting body. It was further discovered that virus-like particle were present in several mushrooms-not only in *Lentinus edodes*.

ANTITUMOR EFFECTS

The virus like particle from *Lentinus edodes* is able to suppress the Ehrlich ascitics carcinoma in mice. Antitumor activity is not unique to *Letinus edodes*, since it is also present in other mushrooms. However, since the late 1970s, most research efforts has been put into study of *Lentinus edodes*. Much literature has accumulated about anti-tumor activity of *Lentinus edodes*, with most information being concerned with the identification and purification of the responsible ingredients but not with the mechanism of action. Chihara *et al.*,(1969) reported that a water soluble polysaccharide fraction from a fruiting body of *Lentinus edodes* could inhibit the growth of mouse Sarcoma 180 in mice, and even complete regression was observed in swiz albino mice. The dosages for bio assay were ranged from 1-10 mg/ kg body weight and were given intra –peritoneally.

Fujii *et al.*,(1978) isolated and characterized a new antitumor polysaccharide , KS-2, which was excreted from the cultured mycelia of *Lentinus edodes*. KS-2 mainly composed of α-alanine . Its molecular weight is approximately 60,000- 95,000. KS-2 suppressed sarcoma 180 as well as ehrlich ascites carcinoma in mice when given orally or Intraperitoneally; Moreover, it could induce interferon production in mice.

Sugano *et al.*, (1982) even detected the anticarcinogenic actions of water soluble and alcohol insoluble fractions from the culture medium of *Lentinus edodes mycelia*. The alcohol insoluble fractions were composed of a Xylose – containing polysaccharide and protein. Ehrlich ascites carcinoma in mice was used as a bio-assay system in this study.

CARDIOVASCULAR AND RENAL EFFECTS:

Volvatoxin A is cardiotoxic protein from *Volvariella volvaceae*. In isolated toad hearts, the toxic protein caused ventricular systolic arrest at dose of 0.1mg/ml; in cats i.v. injection of protein produced changes in the electrocardiogram (ECG) at a dose of 0.7 mg/kg body weight. It depressed the ST segment and inverted the T- wave, But no significance changes in the blood pressure were noted.

Chronic ingestion of *Lentinus edodes* was reported to reduce the serum cholesterol level in human subjects and hypertension is attributable to a high serum cholesterol level. An antiplatelet substance was isolated from the aqueous extract of *Auricularia polytricha*. This antiplatelet substance could inhibit platelet aggregation. This substance was later identified to be adenosine and was suggested to be responsible for the low incidence rate of arthrosclerosis among Asians who consumed *Auricularia polytricha* regularly.

An aqueous extract from *Pleurotus sajor-caju* was associated with the hypotensive action that could reduce the Glomarular Filtration Rate (GFR) in rats. The hypotensive action was mediated by interferin with the rennin – Angiotensin system like converting enzyme inhibitor. The clinical implication of GFR reducing effect is to reduce the rate of nephron deterioration and thus extent life span of chronic renal failure patient, but the mechanism of action is unknown. Bailey *et al.*, reported that *Coprinus comatus* can lower the blood glucose in mice. Normal mice were fed a diet containing powdered dried fruiting body of *C. comatus* (33.3% W/W). Plasma glucose concentrations were reduced after 11 days, and intraperitoneal glucose tolerance was improved

PROTEIN GAP AND TODAY'S WORLD PROBLEM:

Maximum output with minimal land available.

When One acre land is used for cultivation of Rice, 30% conversion as protein was achieved; when it was used for dairy development, 50% conversion as protein is possible. Sixty percent conversion as protein can be achieved if piggery was practiced. But positively by mushroom cultivation, 90-100% conversion as protein can be achieved.

Presently (2008) the world population is 6.7 billion. In 2050 (addition of 2.5 million) population will cross 9 billion. We need an addition of 1600 sq.km of good farm land. Just to feed annual increase of 78 million people. Already the farmland is shrinking hence the question of increasing the farm land will be a Herculean task or it may be destroying already dwindling forests.

In 1970 due to oil prices hike in food prices has grown up and food prices become doubled. In 2008 though the food production is more, food is under short supply, since food, cereals, grams are used as raw material for the alcohol (a bio-fuel) production to satisfy energy need and to replace the dwindling fuel petrol. Food riots have been reported from a number of countries including Bangladesh, Egypt, Haiti and the Philippines. Elsewhere the prices of edible commodities are hitting the roof. Jacques Diouf, FAO director general, has gone on record to warn that despite an expected 2.6 per cent rise in world cereal output this year, food grain prices are not likely to fall and the food import bills of poorer countries might go up by almost 56 per cent. Problem is when it comes to basic food items, market forces don't help. Food supply being inelastic to price in the short term, however high the latter may go, supply cannot be increased immediately (Satish K. Sharma, 2008). No Free Lunches A worldwide food crisis could be only a generation away. Unless there's some dramatic development to reverse, existing trends, the maths is simple. The world population at present is 6.7 billion: With UN projections of an additional 2.5 billion people in the next four decades, this will cross nine billion by 2050. The Earth Policy Institute in Washington estimates that it requires about 1,600 square kilometers of

good and new farmland just to feed t}le annual increase of 78 million people, most of them in countries least able to grow food (Prachanda, 2008).

Drought in Australia has lead to international shortage of wheat. An export ban on rice has pressured the international rice supply. Increase in demand of cereals from the livestock sector for feed, the use of cereals for bio-fuel has further diversified the use of grains. Thus in the present time, high fuel costs, of cereals for stabilizing prices, it would definitely lead to some inflation. (National Centre for Agricultural Economics Policy Research, 2008).

Fungi have many keys because mushroom cultivation the land was utilized not only the horizontal area but also vertically to unlock not only the present day problem but also problems of the future. The solution what can say is utilization of microbes especially by cultivating edible mushrooms. Since maximum protein output with minimal land available can be achieved efficiently when compared to all the other forms of agriculture. From one acre land protein derived by cultivating all other commodities are less compared to mushroom cultivation (Table 1, 2)

Non Target effect

Green Revolution had increased food production with the excessive use of chemical fertilizer, fallowing of fertile soil. Now 11.6 Million Hectares are less productive in India alone.

Besides chemical fertilizers, large areas of fertile lands have been polluted with various effluents from leather textile, and chemical industries. These pollutants have to be removed in order to replenish with nutrients. This has been achieved by incorporating fungal compost. This compost has enzymatic machinery to mineralize these pollutants into simple compounds. Now it is high time to think about the task ahead of every nation

1. Increase yield of crop by replenishing the soil by replacing chemical fertilizers with organic fertilizers.

2. Production of organic fertilizers, increase the protein yield per acre of land utilized and per utilization of raw materials.

3. Pollutants have to be removed in order to replenish with nutrients

Fungi have key to unlock the present day problems and problems of the future. The solution what we can say is utilization of microbes especially by cultivating edible mushrooms and by incorporating the spent compost and compost of potential fungi to perform specific degradation of pollutants; we can achieve these targets easily.

NEED OF THE HOUR

- Revival of Soil fertility
- Enrichment of Soil fertility

REVIVAL OF SOIL FERTILITY

Inoculation of Mycorrhizal (fungus root symbiotic, Non-pathogenic or feebly or weekly pathogenic) fungi in contaminated soils will help in the recovery of soil. It is because these fungal hyphae accumulate those minerals in their cells. 85 % of plant species. Plant species richness is related to mycorrhizal species richness (Johnson *et al.*, 2005). Since more than 25% of root biomass consists of EM fungi- major structural component of forest ecosystem. Nutrients from trees that are well exposed to sunlight transported to trees under shades through hyphae of mycorrhizal fungi now known as Wood Wide Web (WWW). Ninety percent (90%) of total living organisms found in healthy forest soils are fungi. Fungal species richness is equal to plant species richness. About 25% of EM root consists of fungi.

ENRICHMENT OF SOIL FERTILITY

The largest fungal colony to date have been found in *Armillaria*, a parasitic fungus (15 ha and 1500 years old). These fungi accumulate the minerals and organic nutrients in their cells and keep the soil nutrient rich. Minerals are locked in the cells - even during flood these nutrients are not washed off from the soil. Soil nutrition is maintained.

SYSTEMATIC COMPOSTING FOR SAFER ENVIRONMENT

Environmental applications

Many of these mushrooms are primary degraders and degrades the substrates without any pretreatment. By cultivating mushrooms on the farm wastes can be easily be converted into nutrient rich mushrooms. When lignocellulose are degraded, many oligosaccharides are released which readily attract free living nitrogen fixing bacteria such as *Azotobacter chroococcum* and *Azospirillum sp.* They fix atmospheric nitrogen, resulting with nitrogen enriched spent compost (50 to 200%more nitrogen) which can be used as biofertilizer. Our lab has identified potential degraders with efficient enzymatic machinery. Using these fast growing fungi we have formulated inoculum for degradation of municipal wastes. Further, these fungi can break the phenolic rings present in the lignin molecules. Many pollutants such as textile dyes, leather processing effluents are also having same phenolic rings. Hence by incorporating the spent compost and compost of potential fungi ,to perform non - specific degradation of pollutants. By applying this process of applying compost pollutants are not removed but the soil will be enriched with nutrients to enhance the plant growth easily.

How Public can help in biodocumentation?

In Tamil Nadu / India the mushroom eating habits are prevailing in many places. But that knowledge on edibility has to be passed on to the Universities and other research institutions in order to characterize those mushrooms. Thus the traditional indigenous knowledge will be preserved and served to the society back. For this we are planning to organize fungi Map group in each village and also especially in the forest areas. They will be given one day training in collection and the characters to be observed and recorded. The photographing of specimen will be taught. This will not duly inculcate the knowledge of biodiversity of these neglected groups and also help to preserve them by educating the participants their important role in soil nutrition.

Bio-documentation of such mushrooms (*Agaricus heterocystis* and *Lentinus* spp.) are being characterized. This knowledge may serve in the increase of mushroom production and also generate employment in our country.

Training on Mushroom Cultivation:

These are the mushrooms industrially cultivated. To spread this technology and to do further research a National centre has been developed at Solan Himachal Pradesh. In Tamil Nadu both Tamil Nadu Agriculture University and our department (CAS in Botany) conducing a research and training course, in mushroom cultivation. Interacted people approach them for undergo training.

Role of Wood-Degrading Fungi and Environmental biotechnology:

The wood degrading fungi play an important role in nature; they mineralize the lignocellusolic material resulted due to photosynthesis and release the carbon nitrogen and some minerals which are in turn absorbed by the higher plants and other organisms. They in habitat the live, dead or foiled tree trunks, roots and coppiced stools. Thus these fungi play vital role in maintaining natural dynamics of the forest by removing matured plants and thereby giving a wide scope of growth of young plants.

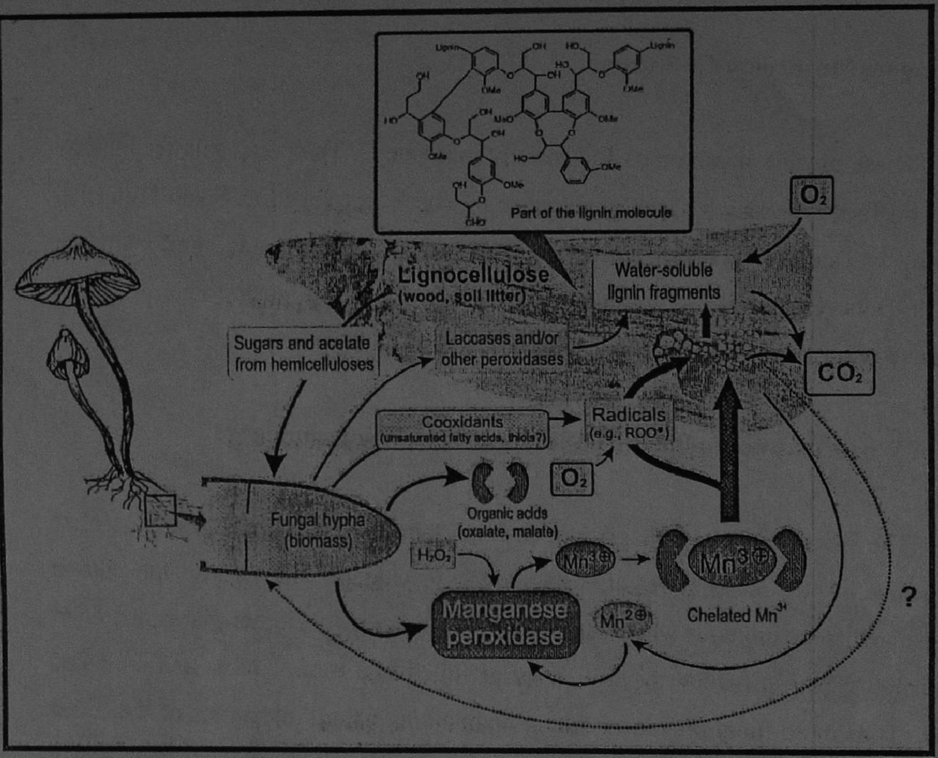


Fig.5: Lignin degradation by basidiomycetous fungi (e.g., *Nematoloma frowardii, Phlebia radiata*). Fungi utilize preferentially sugars and acetate residues from hemicelluloses as carbon and energy source, while lignin is unproductively degraded ("enzymatic combustion") and the major part of cellulose remains fairely unused giving white-rotted wood its characteristic appearance (modified after Hofrichter, M., 2000, BioSpektrum 6: 198-199).

Many wood decaying fungi belongs to polypore are proved to be medicinally important. The medicinal properties such as anti-filamentory anti-tumor, anti-HIV, antiviral, and hypoglycemic etc were attributed to *Ganoderma lucidum, Lentinus edodes* and many *Pleurotus* spp. By mushroom cultivation, the agro wastes are effectively used to produce protein rich edible mushrooms. Besides the substrates (agrowastes) are easily degraded and enriched with more nitrogen/ protein. Hence they are used as value added animal feed or as nitrogen riched fertilizer. In addition, these substrates are used to produce industrially important enzymes such as laccase, protease, pectinase and cellulase. By growing the organisms on solid agro wastes the enzyme production was 10 times higher and economically viable. The enzyme rich material can be used to remove pollutants from the soil effluents. Since the mycelium colonized on the substrate can be amended in the polluted place, by which their

survival rate is increased to 70-80% than the application of mycelium alone. (Kaviyarasan and Siva 2007)

BIOREMEDIATION

With in the course of evolution, only certain basidiomycetous fungi have developed an efficient enzyme system to degrade lignin so that these microorganisms play an important role in maintaining the global carbon cycle (Griffin, 1994). Due to their ability to selectively remove lignin, while leaving white-rot fungi. Typical representatives of these fungi are the wood degraders *Trametes versicolor, Phanerochaete chrysosporium, Pleurotus ostreatus*, and *Nematoloma frowardii* as well as the litter decayers *Stropharia rugosoannulata, Mycena galopus*, and *Agrocybe Praecox*. Lignin degradation does not provide a primary source of carbon and energy for fungal growth and is, therefore, a general co metabolic process (mostly hemicelluloses are used as growth substrates; Eriksson *et al.*, 1990).

In Germany, the TNT persisting in most of the bombed soils were treated with the mushroom mycelia on the compost and degraded (Fritcher -2002). Recently our lab has also demonstrated that these wood rot fungi can be used in degradation of dyes in the effluent. (Fig. 5)

Lignin degradation is very probably brought about the synergistic cooperation of different ligninolytic enzymes. Three phenol-oxidizing enzymes- manganese peroxidase (MnP), lignin peroxidase (LiP) and laccase-are generally thought to be responsible for the unspecific attack of lignin (Hatakka, 1994). Both peroxides are ferric iron containing hemeproteins requiring peroxides (eg. H_2O_2) for function, and laccase belongs to the copper containing blue oxidases which use molecular oxygen (O_2).

Selected Organopollutants that are transformed or mineralized by lignolytic Basidiomycetes and or their lignolytic enzymes (according to Sack *et al.*, 1997, Haas *et al.*, 1998; Hofrichter *et al.*, 1998.)

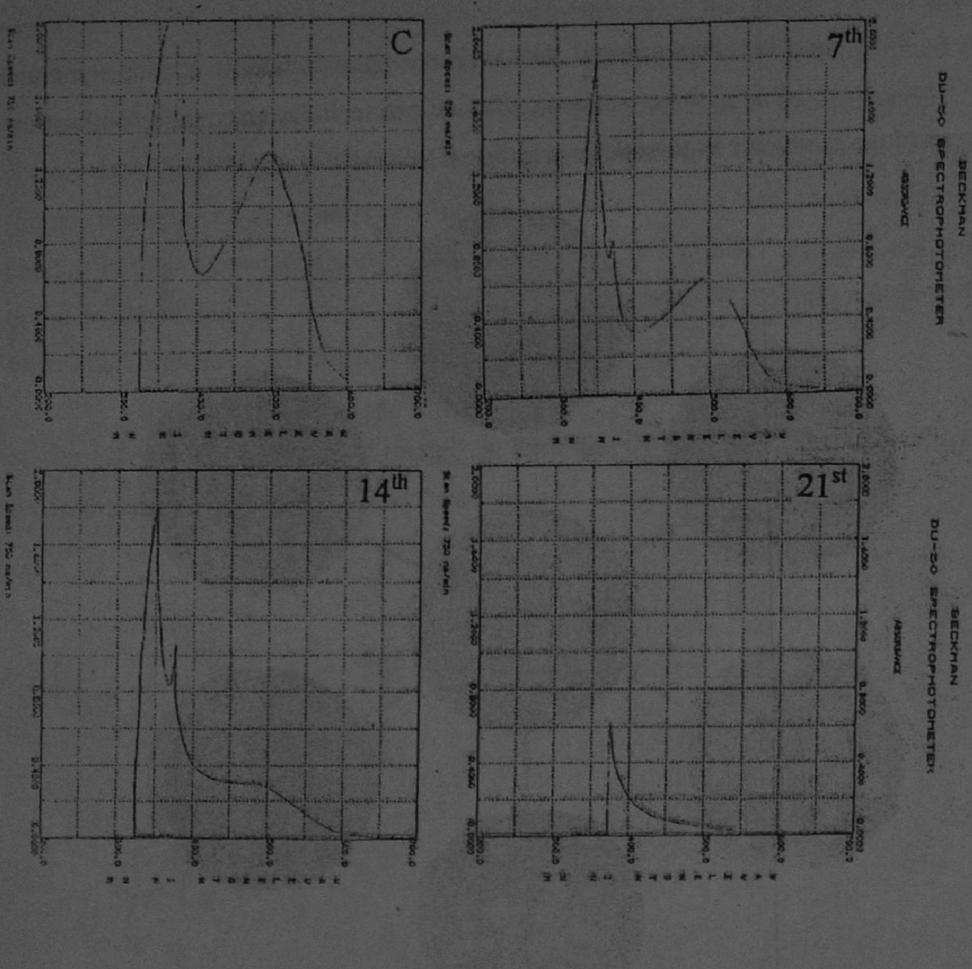
Table.8: White rot fungi employed in degradation of organopollutants

FUNGUS	ORGANOPOLLUTANTS
Bjerkandera adusta	benzo (a)pyrene, other PAHs, TNT, dyes
Nematoloma frowardii	benzo(a)pyrene, other PAHs, TNT, DCP, PCP, AsO
Phanerochate chrysoosporium	benzo(a)pyrene, other PAHs, BTX, DNT, TNT ,DDT, DCP, PCP, PCBs, DCA, dyes, polystyrenes, KCN
Phanerochaete sordid	PAHs, polychlorinated DBDs and DBfs
Pleurotus ostreatus	Phlebiaradiate, TNT, dyes, benzo(a)pyrene, other PAHs, dibenzothiophene, TNT.
Stropharia rugosoannulata	DCP,PCP,TNT
Trametes versicolor	benzo(a) pyrene, other PAHs, DCA, DCP, PCP, dyes.

(AsO: arsenic containing organic compounds, BTX: benzene, toluene, xylenes. DCA:3,4-dichloroaniline. DCP: 2,4-dichlorophenol, DBDs: dibenzo p-dioxins, DBF: dibenzofurans, DNT: 2,4- dinitrotoluene, DDT:1.1.1.-trichloro2.2'-bis(4-chlorophenyl) ethane. KCN: potassium cyanide, PAHs: polycyclic aromatic hydrocarbon, PCBs: polychlorinated biphenyls, PCP:pentachlorophenol, TNT:2,4,6-trinitrotoluene.)

Fig.6:

Spectral characteristics of Congo Red (Azo dye) during the growth of *Pleurotus ostreatus in vitro*



The unique ligninolytic enzyme system of basidiomycetous fungi having based on a high reactive free radical depolymerization mechanism would be ideal for the biodegradation of organo pollutants in the environment (Fernando and Aust, 1990). Compared to other potential bioremediation systems, the extracellular, non-specific, non-stereo selective lignin-degrading system of basidiomycetus fungi has the advantage of being applicable to a variety of recalcitrant and toxic chemicals. Examples for such chemicals and selected fungi responsible for the biodegradation are given in Table.8. Among these substances are hazardous xenobiotic compounds like polychlorinated dibenzodioxins and dibenzofurans, other chlorinated aromatics,

nitro aromatic compounds (explosive), and cancerogenic organo pollutants belonging to the polycyclic aromatic hydrocarbons. MnP, LiP and laccase have been shown to be involved in the transformation of organ pollutants (Bollag, *et al.*, 1988; Barr and Aust, 1994; Hofrichter *et al.*, 1998a).

It was also demonstrated that various organopollutants can be mineralised directly in cell free systems indicating that an extracellular enzymatic combustion of hazardous chemicals is possible in principle (Hofrichter *et al.*, 1998).

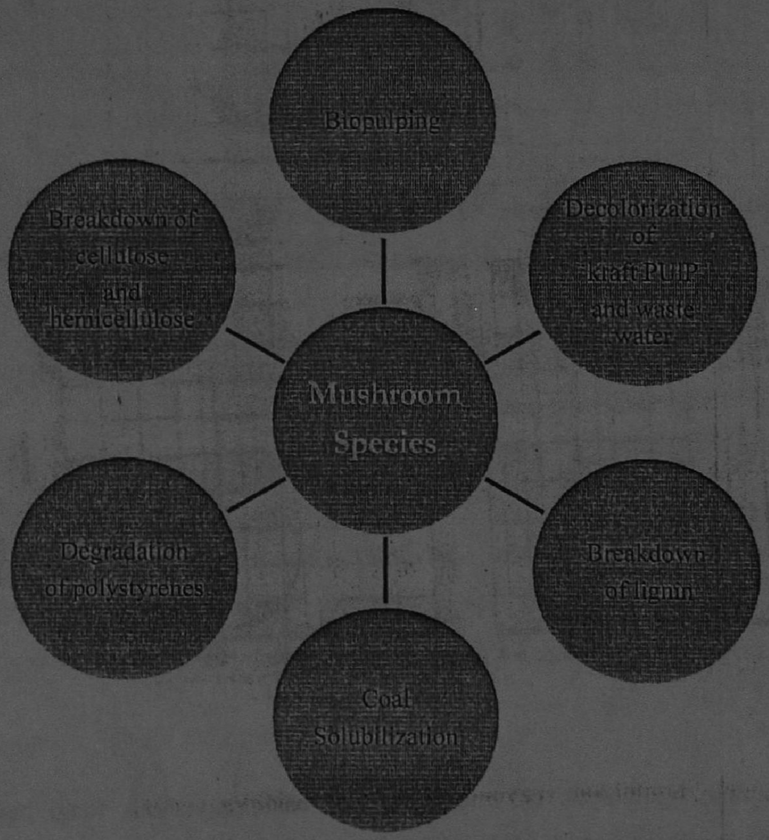


Fig.6: DIAGRAMMATIC REPRESENTATION OF (A) BIODEGRADATIVE AND (B) BIOSYNTHETIC CAPACITIES OF MUSHROOMS

Research has recently been focused on litter decaying basidiomycetes which naturally colonize the upper soil layers. *Stropharia rugosoannulata* is an example of such a fungus which has already been successfully tested for TNT decontamination of

soils (Herre *et al.*, 1997). It has been said that without microorganisms and their degradative capabilities animal life including humans on the planet would cease to exist within about 5 years. Whether or not this is an exaggeration in time scale, it is true in principle that we absolutely depend on microbial activities for the replenishment of our environment and the maintenance of the global carbon cycle (Ratledge, 1991). Among the substances which can be degraded or transformed by microorganisms are a huge number of synthetic compounds (xenobiotics) and other chemicals with environmental relevance. In nature, all the groups of microorganisms (Fungi, Bacteria and Actinomycetes) work together, of course, and complement one another in their degradative capabilities. Mushrooms as a primary degrader not only thrive by degrading the organic and inorganic wastes but also supply nutrients to other microorganisms and enhance their growth.

Hence, **Give room for mushrooms-** in turn they help in conservation of our environment and secure our stay in the earth.

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